

## REPORT DOCUMENTATION PAGE

Form Approved  
OMB No. 0704-0188

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1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED	
	01/03/06	Final	02/15/03 - 9/30/05
4. TITLE AND SUBTITLE <i>Wind Driven Coastal Distributions of Optical Materials</i>		5. FUNDING NUMBERS <i>N00014-03-1-0407</i>	
6. AUTHOR(S) <i>W.S. Pegan</i>		8. PERFORMING ORGANIZATION REPORT NUMBER <i>N01730</i>	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <i>Oregon State University Corvallis, OR 97331</i>		9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) <i>ONR</i>	
10. SPONSORING/MONITORING AGENCY REPORT NUMBER			
11. SUPPLEMENTARY NOTES			
12a. DISTRIBUTION/AVAILABILITY STATEMENT <i>Unlimited Public Access</i>		12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words)			
<p>For this work we used a Bluefin Odyssey III AUV, equipped with an inline array of optical instrumentation. This included a Wetlabs ac-9 and ECO-VSF backscatter sensor, a Satlantic downwelling irradiance sensor and a Satlantic ISUS nitrate sensor. The AUV collected near-surface measurements of physical and optical properties that were uncontaminated by the presence of the ship. It was also used in an undulating mode to provide high-horizontal resolution of layers. The optical and physical measurements, and the AUV navigational information, were collected concurrently and merged to provide a complete description of water properties along the AUV's course.</p>			
14. SUBJECT TERMS		15. NUMBER OF PAGES	
		16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT

# Wind Driven Coastal Distributions of Optical Materials

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*Award #: N000140310407*

## LONG-TERM GOALS

Our primary goal is improve our understanding of the role of currents associated with coastal upwelling fronts in determining the distributions of bio-optical properties.

## SCIENTIFIC OBJECTIVES

The objectives are to determine:

- How far into the coastal jet are high phytoplankton levels found? Does the jet transport phytoplankton or act as a barrier to phytoplankton transport?
- How is the distribution of optical materials affected by secondary circulation inside of the upwelling front?
- How do the surface currents redistribute optical materials during relaxation events?

## APPROACH

This program of research was conducted in collaboration with work conducted by Tim Cowles, Hemantha Wijesekera and Tim Boyd. The proposals by Wijesekera and Boyd, and Dale and Barth, examine the dynamics of the upwelling front and coastal jet. They examined the physical properties, including currents, in this region. We relied on their expertise in collecting and interpreting the velocity measurements that we are using in our study. Cowles examined the formation and structure of thin layers. A possible formation mechanism is shear flow at the coastal jet and another is the subduction of phytoplankton from the surface. These mechanisms are related to the surface circulation patterns that we studied during this project.

For this work we used a Bluefin Odyssey III AUV, equipped with an inline array of optical instrumentation. This included a Wetlabs ac-9 and ECO-VSF backscatter sensor, a Satlantic downwelling irradiance sensor and a Satlantic ISUS nitrate sensor. The AUV collected near-surface measurements of physical and optical properties that were uncontaminated by the presence of the ship. It was also used in an undulating mode to provide high-horizontal resolution of layers. The optical and physical measurements, and the AUV navigational information, were collected concurrently and merged to provide a complete description of water properties along the AUV's course.

Areas of potential interest were identified using surveys provided by Andy Dale. He surveyed the region using a Mini-Bat, and provided larger spatial resolution than the AUV can provide. The Mini-

Bat survey was completed first, and the AUV and the bio-optical profiling equipment of Cowles was then used to provide high spatial resolution measurements of optical and physical properties. A variety of nesting schemes were used including: large survey with Mini-Bat with finer survey with the AUV with occasional profiles for high resolution; continuous profiling at one location with the AUV surveying around the vessel, and horizontal transects using the AUV for statistical analysis.

## WORK COMPLETED

The AUV arrived at Oregon State University in November 2002 and was accepted in December of that year. A number of modifications were made to the AUV platform in preparation for deployment. An ISUS nitrate sensor was integrated into the payload, replacing a camera system. A third battery was added to the AUV, greatly increasing the length of missions before recovery and recharge is necessary. The nose cone was modified to reduce vibration in the microstructure package.

The AUV was successfully deployed on two research cruises. The first was undertaken in May 2004 on the R/V MacArthur, in which a week was spent investigation the Columbia River plume with both the AUV and CTD casts.

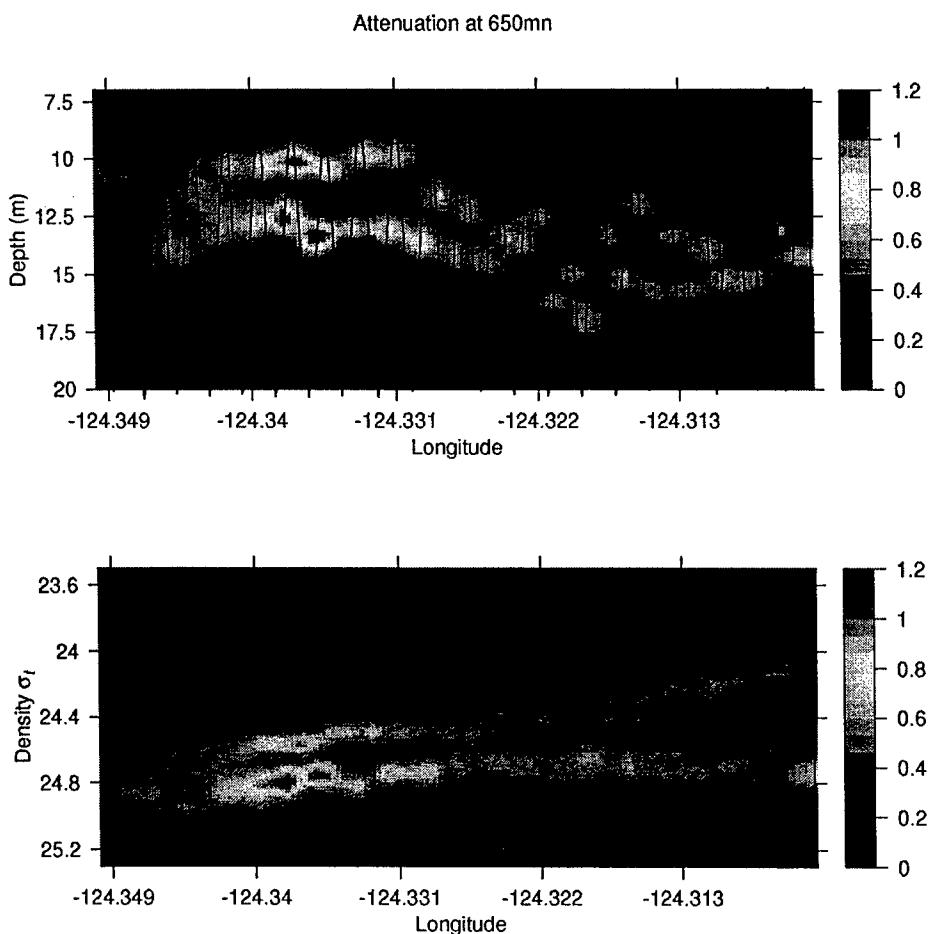
The second was a 10-day cruise at the end of August 2004 on the R/V New Horizon off the Oregon coast. The AUV was deployed in co-ordination with Mini-Bat surveys, CTD casts and Bio-optical casts. Several types of missions were accomplished: 1) undulating (Yo-Yo) missions focusing on a thin layer, 2) fixed depth missions for examining horizontal space scales, 3) undulating missions around the ship as it profiled to provide spatial context to high-vertical resolution CTD casts, and 4) undulating missions nested within a concurrent minibat survey. Missions lasted up to eight hours and were not limited by battery power, but instead by retrieval conditions that tended to deteriorate during the late afternoon. The optical and physical data has been processed for this cruise. Preliminary analysis of the data is completed and two manuscripts have been submitted.

## RESULTS

The two cruises provided the opportunity to learn the best way to use the AUV alongside other instrumentation. The technique of performing large area surveys with a Mini-Bat, and then using these surveys to decide the areas of interest to investigate with the AUV, worked very well. CTD and bio-optical casts could also be performed during AUV deployment if the AUV mission was planned such that vessel could leap frog the AUV between casts – allowing the ship to remain in contact with the AUV. The lessons learned on the cruises will help guide the planning of future collaborative deployments.

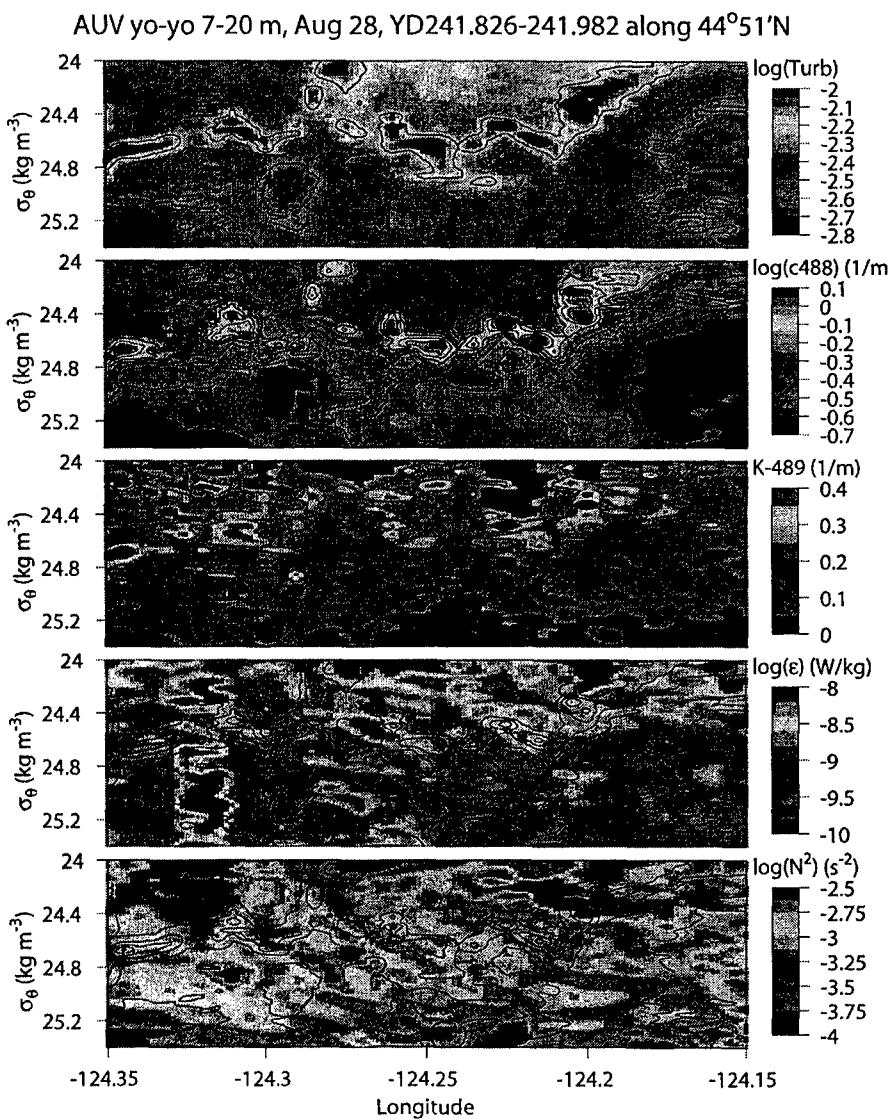
Thin layers of optical materials were observed along the Oregon shelf throughout the August 2004 cruise. In some cases the optical materials were located for distances along isopycnals (Figure 1.), yet in other cases they were located across isopycnals (Figure 2). In all cases thin layers were only found in areas with low turbulent kinetic energy. The presence of internal waves masked the connectivity of the thin layers when plotting optical property versus depth and distance. We are continuing to analyze the relationship between these thin layers and the circulation associated with the upwelling front, as well as their relationship to the upwelling relaxation event that occurred during this observation period.

A series of constant depth missions were conducted during the August cruise. During these missions the AUV was flown along an isobar, repositioned, and then flown back along the track line along another isobar. This was repeated for five isobar levels between 2 decibar and 10 decibar. We found that the variability in the inherent optical properties was primarily at scales of 100 m and larger (Figure 3), especially near the surface (Wijesekera et al., 2005). Variability in IOP occurred at slightly shorter length scales deeper in the water column because of the presence of a biological layer that undulated through the water column. A similar analysis of the downwelling irradiance showed that the variability in the light level is more depth dependent (Figure 3). Near the surface the variability is nearly white with variability seen at nearly all spatial scales. A roll-off begins to occur at a scale of about 2 m. Part of this roll-off is likely to be caused by the response rate of the irradiance sensor. The difference in the wavenumber spectra of the IOP and AOP measurements show that the variability in the light field is more dependent on the air-sea interface than on the IOPs at least in the upper 5 m of the water column.

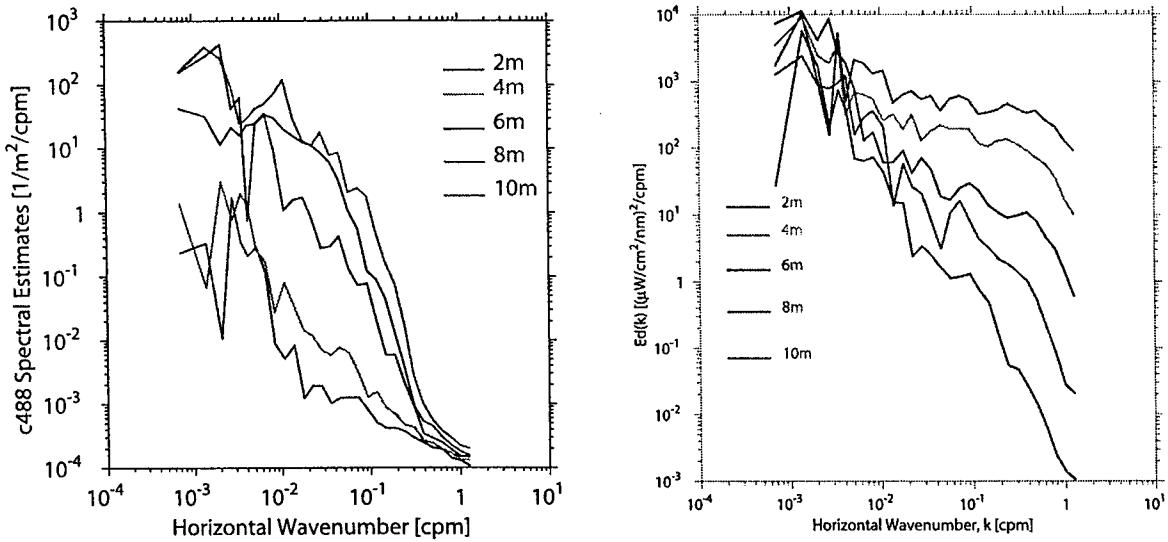


**Figure 1. Beam attenuation at 650 nm collected using the AUV.**

[In the top panel the attenuation is plotted against depth (attenuation is shown in color with red high and blue low values), showing fine structure in the optical signal over the depth range 9 to 16 meters. The AUV track is indicated in black in this panel. The bottom panel gives the beam attenuation, this time plotted against sigma-t. The beam attenuation now indicates two distinct, continuous thin layers, which internal wave activity obscured in the top plot.]



**Figure 2. Optical and turbulence properties plotted as a function of isopycnal (vertical axis) and longitude (horizontal axis).  $\sigma_t$ - longitude fields (interpolated) of turbidity from turbidity sensor in the microstructure package (top),  $c_{488}$  from AC9 (second), the diffusive attenuation coefficient for downward irradiance at 489 nm wavelength (third),  $K_{489}$  ( $=d[\ln\{E_d489\}(z)]/dz$ ), TKE dissipation rate (fourth), and buoyancy frequency squared (fifth panel). Thin lines plotted in bottom two panels represent contours of turbidity. Turbulent mixing tends to destroy the thin layer structure and the majority of layers were associated with regions of weak mixing. Note that the layers shown above do not locate at constant density surfaces in this case.**



**Figure 3. Left panel.** The horizontal wavenumber spectra of the beam attenuation measured at 488 nm by the ac-9 within the AUV. Measurements are from 2 to 10 m depth in 2-meter increments. Most of the energy in the IOP measurements are at scales of 100 m or longer. **Right panel.** The horizontal wavenumber spectra of the downwelling irradiance at 488 nm measured atop the AUV. In this case the wavenumber spectra have more energy at all length scales for measurements near the surface. This is an indication of the importance of the air-sea interface in determining the light field near the surface.

## IMPACT/APPLICATIONS

None

## RELATED PROJECTS

None

## REFERENCES:

Wijesekera, H. W., W. S. Pegau, and T. J. Boyd, The effect of surface waves on the irradiance distribution in the upper ocean, *Optics Express*, **23**, 9267-9264, 2005.

## PUBLICATIONS

Wijesekera, H. W., W. S. Pegau, and T. J. Boyd, The effect of surface waves on the irradiance distribution in the upper ocean, *Optics Express*, **23**, 9267-9264, 2005.

Wijesekera, H. W., T. J. Boyd, W. S. Pegau, and A. Dale, AUV-based observations of small-scale mixing in coastal fronts, submitted to *Geophys. Res. Lett.*